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# Fenestrated endografting of juxtarenal aneurysms after open aortic surgery

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**Introduction:** Juxtarenal aneurysms after previous surgical aortic reconstruction constitute a complex clinical scenario. Open redo surgery is technically demanding and usually requires suprarenal or supraceliac clamping. Standard endovascular repair is prohibited due to the lack of a proximal landing zone. We present our experience with fenestrated endovascular aneurysm repair (F-EVAR) in the treatment of juxtarenal aneurysms after previous open surgery.

**Methods:** A prospectively maintained database including all patients with juxtarenal abdominal aortic aneurysm after previous surgical reconstruction that underwent F-EVAR within the period from November 2003 to February 2013 under the instruction of the senior author. Evaluated outcomes included initial technical success and operative mortality and morbidity as well as late survival, target vessel patency, aneurysm diameter regression, renal function, and reintervention.

**Results:** A total of 35 patients (33 male; mean age,  $71.5 \pm 6.2$  years) were treated. Median interval from the primary surgical reconstruction was 126 months (range, 48-223 months). All patients had proximal anatomies precluding standard endovascular techniques and were considered high risk for open repair due to their comorbidities and redo nature of the operation. In total, 111 vessels were targeted: 77 with small fenestrations, 33 with scallops, and 1 vessel with a downward branch. The operation was completed by totally endovascular means in 34 patients (97.1%). In one patient, a retroperitoneal approach was needed to gain retrograde access to a renal artery. Operative target vessel perfusion success rate was 100%. Operative mortality was 0% and median hospital stay 6 days (range, 2-40 days). Mean follow-up (FU) was  $37.5 \pm 25$  months. Mean aneurysm maximal diameter decreased from  $60 \pm 4$  mm to  $47 \pm 8$  mm ( $P < .05$ ). No type I endoleak was diagnosed, and no reintervention was required during FU. There were eight late deaths, all unrelated to the aneurysm. Estimated survival rates at 1, 2, and 4 years were  $92.0 \pm 5.5\%$ ,  $82.8 \pm 7.9\%$  and  $76.9 \pm 9.3\%$ , respectively. Three target vessel occlusions occurred during FU. One patient suffered a bilateral renal artery occlusion resulting in dialysis. In a second patient, one renal artery occluded without clinical symptoms. No other cases of renal function deterioration were observed.

**Conclusions:** F-EVAR is a valid treatment option for juxtarenal aneurysms after previous surgical reconstruction. F-EVAR represents a less morbid alternative to redo open surgery, has a high technical success rate, and shows durability in mid-term FU. (J Vasc Surg 2014;59:307-14.)

Open infrarenal aortic reconstruction can be complicated by proximal para-anastomotic aneurysms (PAAs) or progressive aneurysmal degeneration of the native aorta. These complications are uncommon and usually appear years after the initial operation but constitute a challenging clinical scenario.

Open repair is technically demanding and often requires suprarenal or supraceliac clamping, which has been associated with considerable mortality, morbidity, and

deterioration of renal function.<sup>1-3</sup> The redo nature of the operation poses additional problems and further increases postoperative complication rates.<sup>4</sup> Use of an infrarenal proximal stent graft (ie, a cuff) can be a viable alternative to open redo surgery in selected patients who still have a suitable proximal landing zone.<sup>5</sup> However, in most patients, a suitable proximal neck is lacking, therefore prohibiting standard endovascular aneurysm repair (EVAR).

Fenestrated EVAR (F-EVAR) is, meanwhile, an established method in the treatment of short-necked and juxtarenal aneurysms. Reported studies show favorable early and midterm outcomes.<sup>6-9</sup> F-EVAR can be a viable alternative in the treatment of juxtarenal aneurysms after previous standard EVAR.<sup>10</sup> F-EVAR has also been used to treat patients with proximal aortic pathology after surgical reconstruction, although reported data are sparse.<sup>11,12</sup> We have previously published our initial experience and now report our midterm outcomes in 35 consecutive patients 10 years after introduction of the method for patients after failing open repair.<sup>13,14</sup>

## METHODS

All patients with juxtarenal abdominal aortic aneurysms (AAAs) after surgical aortic repair treated with F-EVAR

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from November 2003 to February 2013 under the instruction of the senior author (E.V.) were included in this study. Data were collected prospectively. All patients had an infrarenal neck length of  $\leq 10$  mm, precluding treatment with a standard infrarenal device. The diameter of fenestrated grafts ranged from 22 to 36 mm to accommodate proximal aortic diameters ranging from 20 to 32 mm. Patients with insufficient paravisceral fixation or a thoracic component to the aneurysmal degeneration were excluded from the study. This is because of significant differences in stent graft design associated with the use of composite thoracoabdominal, predominantly branched, stent grafts in the latter category. Open redo surgery with renal artery reimplantation was carried out in three patients with a juxtarenal aneurysm in the early study interval. From 2006, all patients with juxtarenal aneurysms after surgical reconstruction have been treated with F-EVAR. Preoperative planning was carried out using thin cut ( $\leq 1.5$  mm) spiral computerized tomography angiography (CTA) with axial, coronal, and three-dimensional reconstructions. Additional digital subtraction angiography (DSA) was performed when there was indication that target or access vessel catheterization could present difficulties. The physical status of all patients was assessed preoperatively with the American Society of Anesthesiologists (ASA) score.

All patients were treated with custom-made fenestrated Cook endografts (William A. Cook Australia, Ltd, Brisbane, Australia) based on the Zenith system. A variety of endograft configurations was used, to accommodate individual patient anatomy. In the presence of adequate working length of more than 5 cm from the lowest renal artery to the aortic (neo)-bifurcation, a composite system was preferably applied. In patients with too-short working length, either a fenestrated cuff was used when adequate sealing could be achieved within the previous graft or a bifurcated fenestrated system (with a contralateral limb) when distal landing in the iliac arteries was deemed necessary.

Proximal graft scallops were 10 mm in width and 6 to 12 mm in depth. Since 2004, all scallops were reinforced with nitinol around the perimeter. In the case of accessory renal arteries, the decision to revascularize was determined by the diameter of the artery and the amount of renal volume depending on the vessel. Accessory renal arteries with a diameter  $< 3$  mm were overstented. Fenestrations were either 6 mm  $\times$  6 mm or 6 mm  $\times$  8 mm in size. Initially, fenestrations were stented either with covered or bare metal stents depending on whether the endograft was in apposition to the aortic wall around the vessel orifice. Since 2007, all fenestrations were stented with covered balloon-expandable stents. A variety of bare metal and covered stents was applied for target vessels, reflecting the evolution of the technique. The bare-metal stent used in the beginning of the experience was the Genesis balloon-expandable stent (Cordis, Warren, NJ) with diameters ranging from 5 to 7 mm for the renal arteries and from 7 to 8 mm for the superior mesenteric artery (SMA). Length was 29 or 39 mm for the renal arteries and 39 or 59 mm

for the SMA. The balloon-expandable covered stents used were either Atrium iCAST (Atrium Medical Corporation, Hudson, NH) stent grafts or JOMED (JOMED International AB, Helsingborg, Sweden) stent grafts. The diameter of balloon-expandable covered stents ranged from 5 to 7 mm for the renal arteries and 7 to 9 mm for the SMA. The length of iCAST stent grafts was either 22 or 38 mm for renal arteries and 38 mm for the SMA. JOMED stent grafts were 26 mm in length. Covered stents were deployed aiming for protrusion of the stent graft of 3 to 4 mm into the body of the aortic graft. The portion within the aortic graft was flared using a 12-mm balloon to achieve better sealing and to allow easier access to the visceral vessel if future intervention were to be required. In cases of severe angulation of the target vessel, an additional SMART (Cordis, Warren, NJ) or EVERFLEX (ev3 Inc, Plymouth, Minn) self-expandable bare-metal stent was deployed inside the balloon-expandable covered stent to prevent kinking.

Procedures were performed either in the operating theater using a mobile C-arm (OEM 9800; General Electric Medical Systems, Salt Lake City, Utah, and Arcadis Avantic; Siemens AG, Forchheim, Germany) or (later) in a hybrid operating room with a fixed C-arm system (Artis Zeego; Siemens AG, Forchheim, Germany). The operative technique has been described in detail previously.<sup>7,14</sup> In brief, femoral artery exposure is performed on both sides. The fenestrated graft is introduced via the femoral artery and unsheathed, leaving it partially constrained by its top cap and diameter-reducing ties. Catheterization of the fenestrations or branches is carried out through the contralateral femoral artery. After wire access in all fenestrations has been achieved, the graft is fully deployed. The fenestrations are thereafter fitted with stents or stent grafts. Finally, in case of a composite fenestrated system, the distal bifurcated body is introduced and deployed.

Technical success was defined as an endovascularly completed procedure with absence of type I or III endoleak and patent target vessels.

**Follow-up (FU).** Postoperatively, patients were evaluated with clinical and laboratory examination prior to discharge. FU consisted of CTA at 1 month, duplex ultrasound (DUS) at 6 months, and CTA at 12 months postoperatively. Thereafter, patients were monitored with yearly CTA or solely with DUS and abdominal X-rays in case of complete thrombosis of the aneurysm sack and absence of endoleak. Renal size measurements were carried out on CTA three-dimensional reconstruction images as well as DUS examinations. Renal vessels were investigated for stenosis by means of CTA with planar reconstruction as well as DUS with peak systolic velocity and renal aortic ratio measurements. Upon suspicion of a new endoleak or target vessel malperfusion, DSA was carried out. Serum creatinine and glomerular filtration rate (GFR) levels were monitored at each visit.

**Data analysis.** Data analysis was performed with SPSS for Windows (version 20.0; SPSS Inc, Chicago, Ill). Variables are presented as mean  $\pm$  standard deviation in case

of normal distribution, and median plus range if data had a skewed distribution. Statistical significance was set at  $P < .05$ . Patient survival and target vessel patency was analyzed using Kaplan-Meier methodology.

## RESULTS

**Patient characteristics.** A total of 35 patients (33 male, 2 female; mean age,  $71.5 \pm 6.2$  years) underwent elective F-EVAR for juxtarenal AAA after previous infrarenal surgical reconstruction. Twenty-two (62.9%) patients were classified as ASA III, 12 (34.3%) patients as ASA II, and 1 (2.9%) patient was classified as ASA IV. Mean preoperative GFR was  $52.6 \pm 15.7$  mL/min/1.73 m<sup>2</sup>. Thirteen (37.1%) patients had a GFR  $<60$  mL/min/1.73 m<sup>2</sup>. Other pre-existing comorbidities included coronary artery disease in 25 (71.4%) patients, congestive heart failure in 8 (22.8%) patients, obstructive pulmonary disease in 10 (28.5%) patients, and peripheral arterial occlusive disease in 4 (11.4%) patients.

Median interval from the primary surgical reconstruction was 126 months (range, 48-223 months). Twenty-three (65.7%) patients had been treated with a tube graft and eight (22.9%) with an aortobiliac (ABI) graft. The four (11.4%) patients with concomitant peripheral occlusive disease had previously been treated with an aortobifemoral (ABF) graft. Four of the patients had two previous operations. These included a tube graft followed by another tube graft for a distal anastomotic pseudoaneurysm in two cases, a tube graft followed by an ABI graft in the third patient, and a left iliac stent graft placed for a distal anastomotic pseudoaneurysm after an ABI graft in the fourth patient.

Mean maximal aneurysm diameter was  $60 \pm 4$  mm, and mean infrarenal aortic neck length was  $1 \pm 2$  mm. Mean aortic diameter in the pararenal segment was  $28 \pm 4$  mm. In 14 (40%) patients, indication for treatment was a PAA originating below the level of the renal arteries indicating possible graft-related pseudoaneurysm formation, whereas in 21 (60%) patients, the aneurysmal degeneration encroached on the visceral segment, indicating a proximal progression of disease.

**Operative planning and details.** A fenestrated cuff was used in 9 (25.7%) patients, a bifurcated fenestrated graft in 2 (5.7%) patients, and a composite fenestrated system in 24 (68.6%) patients. Mean proximal diameter of the fenestrated graft was  $30 \pm 4$  mm, and mean limb diameter was  $16 \pm 4$  mm. In one case, the composite system included a Zenith (William A. Cook Australia, Ltd) iliac branched endograft to accommodate an aneurysm of the right common iliac artery. In total, 111 visceral vessels were targeted, 77 with fenestrations, 33 with scallops, and 1 vessel with a downward branch. The target vessel revascularization method is demonstrated in Table I. In 21 (60%) patients, the stent graft was designed to reach the level of the SMA, with the most commonly used configuration in 18 patients including two fenestrations for the renal arteries and a scallop for the SMA. A stent graft including a scallop for the celiac artery was designed in 12 (34.3%) patients. In two (5.7%)

**Table I.** Target vessel revascularization method

Target vessel	Fenestration type			Total
	Fenestration	Scallop	Branch	
RRA	32	2	0	34
LRA	31	0	1	32
SMA	14	19	0	33
CA	0	12	0	12
Total	77	33	1	111

CA, Celiac artery; LRA, left renal artery; RRA, right renal artery; SMA, superior mesenteric artery.

**Table II.** Stent graft configuration with fenestration specification for each vessel

Patients, No. (%)	Fenestration configuration			
	RRA	LRA	SMA	CA
18 (51.4)	Fen	Fen	Scallop	0
10 (28.5)	Fen	Fen	Fen	Scallop
1 (2.9)	Fen	Occl	Fen	Scallop
1 (2.9)	Fen	Branch ↓	Fen	Scallop
1 (2.9)	Fen	Fen	Fen	0
1 (2.9)	Scallop	Fen	Scallop	0
1 (2.9) <sup>a</sup>	0	0	Fen	Occl
1 (2.9)	Fen	0	0	0
1 (2.9)	Scallop	Fen	0	0

CA, Celiac artery; Fen, fenestration; LRA, left renal artery; Occl, chronically occluded; RRA, right renal artery; SMA, superior mesenteric artery.

<sup>a</sup>Patient with bilateral nephrectomy and CA occlusion.

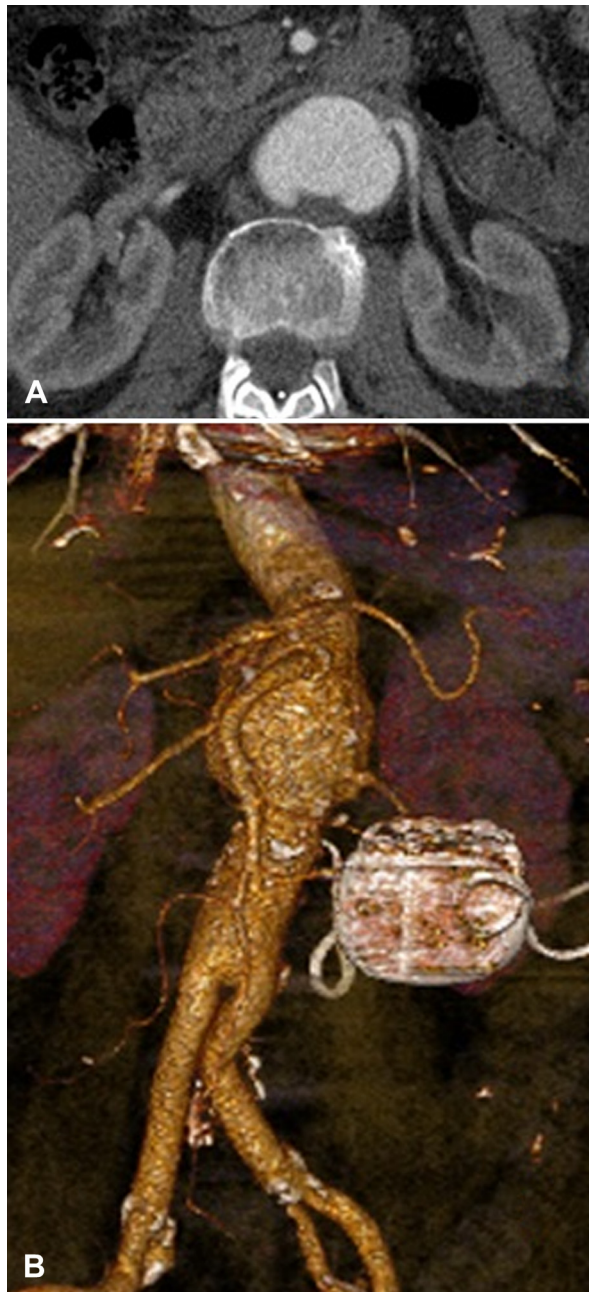
patients, the fenestrations targeted solely the renal orifices. The graft fenestration configurations used are listed in Table II.

Scallops were routinely left unstented, with the exception of one patient where deployment of a bare stent was required due to partial coverage of the renal orifice. Fenestrations were secured with balloon-expandable covered stents in 62/77 (80.5%) cases and with balloon-expandable bare-metal stents in 11/77 (14.3%) cases. In the remaining four (5.1%) cases, a combination of a balloon-expandable covered and a self-expandable bare-metal stent was applied. The one vessel targeted with a branch was secured with a self-expandable covered and a self-expandable bare-metal stent.

The procedure was carried out under general anesthesia in 29 (82.9%) patients and under epidural anesthesia in six (17.1%) patients. Median operative time was 210 minutes (range, 110-420 minutes), and median estimated blood loss was 265 mL (range, 100-1500 mL). Median fluoroscopy time was 41 minutes (range, 8-140 minutes), and mean iodinated contrast volume used was  $180 \pm 54$  mL.

**Technical success.** All patients underwent a successful endovascular repair. In 33 patients (94.2%), F-EVAR was completed solely via a transfemoral approach. In one patient (2.9%), a planned retroperitoneal incision was





**Fig 1.** Spiral computerized tomography angiography (CTA) in axial (A) and three-dimensional reconstruction (B) views demonstrating a stenotic angulated left renal artery with an anterior take-off, catheterized via a retroperitoneal approach.

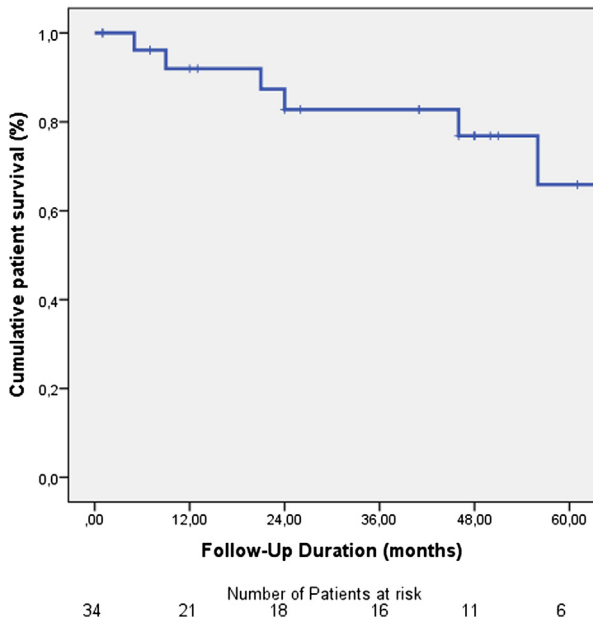
carried out in order to achieve catheterization of a stenotic, angulated, and tortuous left renal artery with an anterior take-off (Fig 1). This patient had undergone additional preoperative DSA via a transfemoral and a transbrachial approach, which demonstrated that the left renal artery was not susceptible to antegrade catheterization. Following exposure of the distal portion of the left renal artery, a 5F

sheath was introduced into the vessel. The fenestration was catheterized in a retrograde manner, and the wire was snared to create a through-and-through wire, to allow for safe stenting. In the second patient, a transbrachial approach was necessary to achieve catheterization of a caudally oriented branch for a severely tortuous left renal artery with aneurysmal, caudally oriented take-off.

Intraoperative technical problems were encountered in nine (25.7%) patients. In one (2.9%) patient, a dense periprosthetic scar led to a difficult exposure of the ABF limb, and direct access through the Dacron graft limb was poorly hemostatic, leading to a large amount of intraoperative blood loss (1500 mL). In another patient, high deployment of the stent graft resulted in malalignment of the fenestrations with the target vessels. During attempts to pull the endograft downward, the bottom stent was deformed, which required placement of a distal aortic cuff. In the remaining seven (14.2%) patients, renal artery catheterization and stent graft deployment were problematic due to severe stenosis and angulation. In two of these cases, passage of a JOMED stent graft into the right renal artery resulted in the stent graft being pushed off of the balloon. Both stents were successfully retrieved and replaced. In the third patient with a severely angulated right renal artery originating from the PAA, catheterization proved extremely tedious and was ultimately achieved with a 0.018" Terumo wire (Terumo Medical Corporation, Somerset, NJ). After introduction of a 7F sheath, the fenestrated graft was deployed completely to create more working room, and the orifice of the renal artery was predilated with a STERLING balloon (Boston Scientific PI, Natick, Mass). The vessel was secured with a balloon-expandable covered iCAST stent and additional deployment of a self-expandable SMART stent to prevent kinking. The same stent combination was applied in two more patients with angulated renal arteries and in the sixth patient with problematic target vessel anatomy due to a short dissection of the left renal artery during catheterization. Finally, the seventh case involved the patient treated with a caudally oriented branch. The left renal artery was severely tortuous, had to be revascularised from a left axillary access, and was secured with a Wallgraft (Boston Scientific PI) and an Everflex bare-metal stent (EV3 Endovascular, Inc).

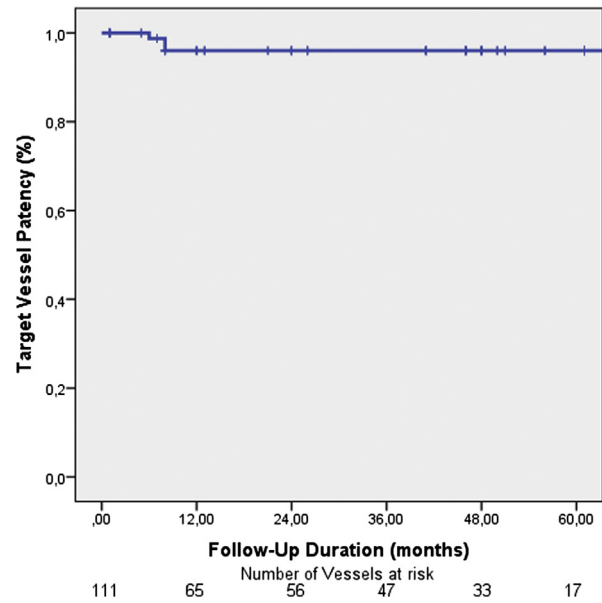
#### **Operative outcome, mortality, and morbidity.**

Surgical mortality at 30 days was null. No case of renal function deterioration >30% was witnessed in the early postoperative period. Mean postoperative GFR was  $51.7 \pm 15.7$  mL/min/1.73 m<sup>2</sup>. Major complications occurred in three (8.6%) patients. The patient who underwent retroperitoneal approach suffered a decompensation of his congestive heart failure with a subsequent myocardial infarction and a prolonged hospital stay of 23 days. A second patient suffered a non-ST segment elevation myocardial infarction on the second postoperative day. Coronary angiography demonstrated no relevant coronary artery stenosis, and the incident was attributed to vasospasm. The patient had a 17-day hospital stay. Both patients were discharged in good condition. The third



**Fig 2.** Kaplan-Meier estimate of the cumulative overall patient survival for all-cause mortality during follow-up (FU).

Time, months	12	24	36	48	60
Number at risk	21	18	16	11	6
Standard error	0.055	0.079	0.079	0.093	0.129



**Fig 3.** Kaplan-Meier estimate of target vessel patency during follow-up (FU).

Time, months	12	24	36	48	60
Number at risk	65	56	47	33	17
Standard error	0.012	0.023	0.023	0.023	0.023

patient suffered a wound dehiscence leading to a prolonged hospital stay of 40 days for wound care, due to the existence of an ABF graft in the groin.

Median hospital stay was 6 days (range, 2-40 days). Treatment in the intensive care unit was necessary solely in the two patients with MI for 9 and 2 days, respectively.

**FU.** Mean FU was  $37.5 \pm 25$  months. Two patients who were referred from abroad were lost to FU after their 1-year FU. Estimated survival rates were  $92.0\% \pm 5.5\%$ ,  $82.8\% \pm 7.9\%$ , and  $76.9\% \pm 9.3\%$  at 1, 2, and 4 years, respectively. Fig 2 demonstrates the cumulative survival curve as estimated by Kaplan-Meier analysis. All-cause late mortality was eight patients, all of them aneurysm unrelated.

During FU, three cases of renal artery occlusion occurred. One patient presented with an asymptomatic right renal artery occlusion at 6 months. This vessel had been targeted with an unsupported scallop and left unstented. No graft migration or kinking that could explain the occlusion was detected on CTA. A second patient presented at 8 months with bilateral occlusion of the renal arteries, originally secured with JOMED covered stents. The patient had unremarkable CTAs at 1 and 6 months and suffered the occlusion after traveling abroad and suffering severe gastroenteritis with volume depletion. This patient presented for FU after dialysis had been initiated in an external hospital. In the remaining 34 (97.1%) patients, renal function and kidney size remained

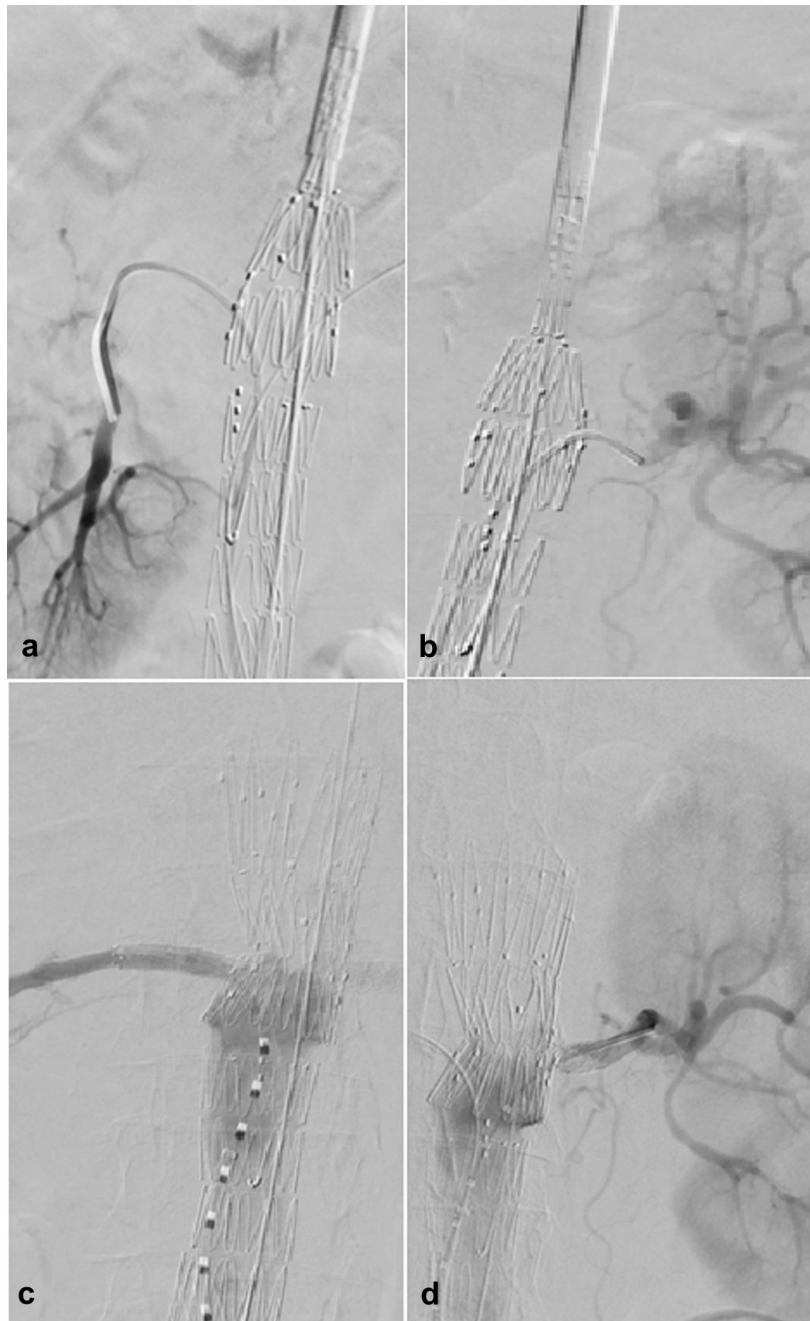
unchanged during FU. No hemodynamically significant visceral branch stenosis was visualized in DUS. Mean GFR during FU was  $52.8 \pm 12.8$  mL/min/1.73 m<sup>2</sup>. Estimated target vessel patency according to Kaplan-Meier analysis is demonstrated in Fig 3.

No limb occlusion or stent graft migration was witnessed during FU. No reinterventions were required. Mean maximal aneurysm diameter decreased from  $60.1 \pm 4$  mm to  $47.3 \pm 8$  mm ( $P < .05$ ).

## DISCUSSION

Open infrarenal repair of AAAs is generally associated with a lower need for reinterventions than EVAR.<sup>15</sup> Although proximal aneurysm formation has been reported in only 3% of patients, it nevertheless poses significant technical problems when considering renewed open repair.<sup>16</sup>

The challenges associated with conventional abdominal aortic redo surgery are considerable and related to increased mortality and morbidity rates, especially when the pararenal segment is involved.<sup>3,17-19</sup> Suprarenal aortic clamping has been shown to significantly increase postoperative renal morbidity.<sup>20</sup> Treatment with standard infrarenal devices can offer an attractive and potentially durable alternative in selected patients, although literature up to now contains relatively few and limited reports.<sup>21-23</sup> A recent study from Ten Bosch et al demonstrated a considerable rate of proximal type I endoleaks and need for reinterventions in patients with proximal PAAs treated with



**Fig 4.** Angiographic images depicting partial deployment of the fenestrated graft (**a** and **b**) to facilitate cannulation of the renal arteries and the fully deployed graft (**c** and **d**) with deployed renal stents.

EVAR, concluding that endovascular repair is only safe and durable in the presence of suitable anatomy.<sup>5</sup>

The present series suggests that F-EVAR can offer a safe and effective alternative in patients with proximal neck anatomy precluding treatment with standard endovascular means. Operative mortality was null, and perioperative morbidity was low in this patient cohort. Hospital stay was lower compared with reported data

regarding redo-open surgery.<sup>23</sup> Target vessel patency remained high during FU, and no reinterventions were needed during midterm FU. F-EVAR led to a significant decrease in maximal aneurysm diameter. To our knowledge, this is the largest study in the literature, with the longest FU on F-EVAR after previous infrarenal surgical reconstruction. Apart from previous reports by the same main author, there are only two papers

describing a similar endovascular approach in nine and three patients, respectively.<sup>11-14</sup>

Despite the high technical success in this series, additional difficulties in planning and execution of the procedure have to be expected when attempting F-EVAR after previous open surgery. Primary F-EVAR nowadays routinely utilizes composite systems consisting of a fenestrated proximal tube graft, which can be freely repositioned facilitating target vessel catheterization, followed by a bifurcated stent graft, and a contralateral limb. This configuration provides additional graft stability and is effective in preventing migration. This configuration is, however, often not applicable in patients previously treated with ABI grafts or ABF grafts due to the usual practice of implanting a short graft body. In cases with a working length too short for a composite system, sealing is achieved solely with a fenestrated proximal cuff. No case of stent graft migration during FU was noticed in the nine (25.7%) patients treated solely with proximal cuffs, but additional surveillance is required to prove the durability of this configuration.

Furthermore, the presence of a previous surgical graft clearly limits maneuverability during deployment of the fenestrated device, due to the relatively small luminal diameter of the surgical prosthesis and the frictional forces between the endovascular and surgical graft. Catheterization of target vessels can be problematic under these circumstances and may require the use of multiple types of catheters and sheaths, or even a retrograde puncture in rare cases. It is furthermore imperative to avoid deploying the fenestrated tube too high, as pulling down the graft in an existing surgical graft is tedious and sometimes not possible. To facilitate repositioning, fenestrated devices are designed to only partially deploy upon retraction of the delivery sheath. The fenestrated tube graft is restrained by incorporated diameter reducing ties, which are removed after successful catheterization of the visceral branches. To accommodate catheterization maneuvers in cases of small luminal diameter of the preexisting graft, double preplaced diameter-reducing restraining ties can be applied. Fig 4 demonstrates a fenestrated graft prior to and following removal of its restraining ties.

Finally, arterial access issues are often encountered in patients with a previous ABF graft. Direct puncture of the ABF limb can result in increased blood loss around the sheaths. Our current practice is to introduce the device through a conduit sewn on the ABF limb. Upon completion of the intervention, the conduit is sewn closed.

This series reflects some of the changes that have taken place in the design of fenestrated endografts since the introduction of this technique. Since 2004, all scallops have been reinforced with nitinol around the perimeter, due to an association of unsupported scallops with vessel stenosis (unpublished data). Similarly, the use of uncovered stents for fenestrations has been abandoned due to an association of uncovered stents with higher rates of stent stenosis. This association was based upon previous unpublished experience and expert consensus meetings in the early days of fenestrated endografting and was later

confirmed by Mohabbat et al.<sup>24</sup> Finally, this series features one patient treated with a single fenestration for a renal artery and one patient with a fenestration for one renal artery and a scallop for the second. These patients were treated early in the series and had one renal artery that was significantly higher than the other. Nowadays, the use of scallops for renal arteries is not advocated. Two fenestrations is the preferable way of treatment to ensure better graft stability.

This study has some limitations. The number of patients is limited. This is a selected patient population, and a certain referral bias has to be acknowledged. Finally, this study reflects the outcomes of two high-volume centers for F-EVAR.

## CONCLUSIONS

F-EVAR is a valid treatment method in cases of PAAs or progressive juxtarenal aneurysmal degeneration after open repair. Although additional technical difficulties in comparison to primary F-EVAR in the native aorta should be acknowledged, it clearly represents a less morbid alternative to open conversion, has a high technical success rate, and has durability in midterm FU.

## AUTHOR CONTRIBUTIONS

Conception and design: KO, EV, IT

Analysis and interpretation: KO, AK, FB, EV

Data collection: KO, AK, FB, EV

Writing the article: KO, AK, FB, EV

Critical revision of the article: KO, AK, IT, EV

Final approval of the article: KO, AK, FB, IT, EV

Statistical analysis: KO, AK

Obtained funding: Not applicable

Overall responsibility: EV

## REFERENCES

1. Jongkind V, Yeung KK, Akkersdijk GJ, Heidsieck D, Reitsma JB, Tangelder GJ, et al. Juxtarenal aortic aneurysm repair. *J Vasc Surg* 2010;52:760-7.
2. Chiesa R, Tshomba Y, Mascia D, Rinaldi E, Logaldo D, Civilini E. Open repair for juxtarenal aortic aneurysms. *J Cardiovasc Surg (Torino)* 2013;54:35-45.
3. Jean-Claude JM, Reilly LM, Stoney RJ, Messina LM. Pararenal aortic aneurysms: the future of open aortic aneurysm repair. *J Vasc Surg* 1999;29:902-12.
4. Locati P, Socrate AM, Costantini E. Paraanastomotic aneurysms of the abdominal aorta: a 15-year experience review. *Cardiovasc Surg* 2000;8:274-9.
5. Ten Bosch JA, Waasdorp EJ, de Vries JP, Moll FL, Teijink JA, van Hervarden JA. The durability of endovascular repair of paraanastomotic aneurysms after previous open aortic reconstruction. *J Vasc Surg* 2011;54:1571-8.
6. Verhoeven EL, Vourliotakis G, Bos WT, Tielliu IF, Zeebregts CJ, Prins TR, et al. Fenestrated stent grafting for short-necked and juxtarenal abdominal aortic aneurysm: an 8-year single-centre experience. *Eur J Vasc Endovasc Surg* 2010;39:529-36.
7. Verhoeven EL, Prins TR, Tielliu IF, van den Dungen JJ, Zeebregts CJ, Hulsebos RG, et al. Treatment of short-necked infrarenal aortic aneurysms with fenestrated stent-grafts: short-term results. *Eur J Vasc Endovasc Surg* 2004;27:477-83.



8. Greenberg RK, Sternbergh WC 3rd, Makaroun M, Ohki T, Chuter T, Bharadwaj P, et al. Intermediate results of a United States multicenter trial of fenestrated endograft repair for juxtarenal abdominal aortic aneurysms. *J Vasc Surg* 2009;50:730-7.
9. Katsargyris A, Oikonomou K, Klonaris C, Töpel I, Verhoeven EL. Comparison of outcomes with open, fenestrated and chimney graft repair of juxtarenal aneurysms: are we ready for a paradigm shift? *J Endovasc Ther* 2013;20:159-69.
10. Katsargyris A, Ozan Y, Oikonomou K, Bekkema F, Tielliu I, Verhoeven EL. Fenestrated stent-grafts for prior endovascular abdominal aortic aneurysm repair salvage. *Eur J Vasc Endovasc Surg* 2013;46:49-56.
11. Adam DJ, Berce M, Hartley DE, Anderson JL. Repair of juxtarenal para-anastomotic aortic aneurysms after previous open repair with fenestrated and branched endovascular stent grafts. *J Vasc Surg* 2005;42:997-1001.
12. Ziegler P, Perdikides TP, Avgerinos ED, Umscheid T, Stelter WJ. Fenestrated and branched grafts for para-anastomotic aortic aneurysm repair. *J Endovasc Ther* 2007;14:513-9.
13. Verhoeven EL, Muhs BE, Zeebregts CJ, Tielliu IF, Prins TR, Bos WT, et al. Fenestrated and branched stent-grafting after previous surgery provides a good alternative to open redo surgery. *Eur J Vasc Endovasc Surg* 2007;33:84-90.
14. Beck AW, Bos WT, Vourliotakis G, Zeebregts CJ, Tielliu IF, Verhoeven EL. Fenestrated and branched endograft repair of juxtarenal aneurysms after previous open aortic reconstruction. *J Vasc Surg* 2009;49:1387-94.
15. De Bruin JL, Baas AF, Buth J, Prinssen M, Verhoeven EL, Cuypers PW, et al. Long-term outcome of open or endovascular repair of abdominal aortic aneurysm. *N Engl J Med* 2010;362:1881-9.
16. Hallett JW Jr, Marshall DM, Patterson TM, Gray DT, Bower TC, Cherry KJ, et al. Graft-related complications after abdominal aortic aneurysm repair: reassurance from a 36-year population-based experience. *J Vasc Surg* 1997;25:277-86.
17. Allen RC, Schneider J, Longenecker L, Smith RB 3rd, Lumsden AB. Paraanastomotic aneurysms of the abdominal aorta. *J Vasc Surg* 1993;18:424-31.
18. Curl GR, Faggioli GL, Stella A, D'Addato M, Ricotta JJ. Aneurysmal change at or above the proximal anastomosis after infrarenal aortic grafting. *J Vasc Surg* 1992;16:855-9.
19. Piffaretti G, Tozzi M, Lomazzi C, Rivolta N, Caronno R, Castelli P. Endovascular treatment for para-anastomotic abdominal aortic and iliac aneurysms following aortic surgery. *J Cardiovasc Surg (Torino)* 2007;48:711-7.
20. Marrocco-Trischitta MM, Melissano G, Kahlberg A, Vezzoli G, Calori G, Chiesa R. The impact of aortic clamping site on glomerular filtration rate after juxtarenal aneurysm repair. *Ann Vasc Surg* 2009;23:770-7.
21. Sachdev U, Baril DT, Morrissey NJ, Silverberg D, Jacobs TS, Carroccio A, et al. Endovascular repair of para-anastomotic aortic aneurysms. *J Vasc Surg* 2007;46:636-41.
22. Mitchell JH, Dougherty KG, Strickman NE, Mortazavi A, Krajcer Z. Endovascular repair of paraanastomotic aneurysms after aortic reconstruction. *Tex Heart Inst J* 2007;34:148-53.
23. Gawenda M, Zaehring M, Brunkwall J. Open versus endovascular repair of para-anastomotic aneurysms in patients who were morphological candidates for endovascular treatment. *J Endovasc Ther* 2003;10:745-51.
24. Mohabbat W, Greenberg RK, Mastracci TM, Cury M, Morales JP, Hernandez AV. Revised duplex criteria and outcomes for renal stents and stent grafts following endovascular repair of juxtarenal and thoracoabdominal aneurysms. *J Vasc Surg* 2009;49:827-37.

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